TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 858

A COMPARISON OF THE RESULTS FROM GENERAL TANK TESTS

OF 1/6- AND 1/12-FULL-SIZE MODELS OF

THE BRITISH SINGAPORE IIC FLYING BOAT

By Starr Truscott and John R. Dawson

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SUMMARY

· A 1/6-full-size model of the hull of the British
Singapore IIC flying boat was tested in the NACA tank.
The results are given in the form of charts and are com-
pared with the results of previous tests made in the NACA
tank of a 1/12-full-size model, published in NACA T.N.
No. 580, and with the results of tests made in the British
R.A.E. tank of another 1/6-full-size model of the same
hull.

When the data from the tests of the 1/6- and 1/12-
full-size models were compared on the basis of Froude's
law of comparison, differences were found. This fact
supported the belief that the small scale of the model
and the use of a model that was too small to suit the
equipment of the NACA tank had caused the results of the
tests of the 1/12-full-size model to be less reliable
than the results of the tests of the 1/6-full-size model.
The results of the tests of the two models agreed suffi-
ciently well to show that tests of a small model, if made
meticulously and with suitable equipment, may give usable
results, but that a larger model should be used whenever
feasible.

The results of the NACA tests of the 1/6-full-size
model were found to be in good agreement with the R.A.E.
tests of a model of the same size.

INTRODUCTION

A 1/6-full-size model and a 1/12-full-size model of
the hull of the British Singapore IIC flying boat have

been tested in the R.A.E. tank and the results of these
tests have been reported in reference 1. The 1/12-full-
size model was later loaned to the NACA by the Director
of Research, British Air Ministry, for comparative tests
in the NACA tank. The NACA tests of the 1/12-full-size
model were reported in reference 2. The model, which was
4 feet 7 inches long, was so small that, although the re-
sults appeared to be fairly good and to compare well with
the results of the tests of the same 1/12-full-size model
in the R.A.E. tank, it was thought probable that tests of
a model better suited to the equipment of the NACA tank
might give somewhat different results. The question in-
volved not scale effect alone but a combination of scale
effect with possible error in the measurement of quanti-
ties that were very near the lower limit of the capacity
of the NACA equipment. It was therefore considered de-
sirable to test a 1/6-full-size model of the Singapore
IIC and provide data for comparison with the NACA tests
of the 1/12-full-size model and the R.A.E. tests of the
1/6-full-size model as well as comparisons with the NACA
tests of a number of other models of approximately the
same size. A 1/6-full-size model reproducing as nearly
as feasible every feature of the 1/12-full-size model was
made and tested in a manner paralleling as far as possible
the tests of the 1/12-full-size model. The tests were
made in 1936. The results of the tests have been presented
in the same form as in reference 1.

THE MODEL

        Photographs of the 1/12-full-size model (model 58)
are shown in figure 1.

        The 1/6-full-size model was constructed from offsets
obtained by doubling those of the 1/12-full-size model.
The model was made of laminated wood, sanded, varnished,
and rubbed. The 1/12-full-size model had been refinished
before it was tested and the finish of the present model
was made the same as that of the smaller model.

        The principal dimensions and ratios of the 1/6-full-
size model are as follows:

Over-all length, in. 109.86
Length, bow to second step, in. 97.20
Forebody length, in. 54.78

Afterbody length (main step to second step),
  in. 42.42
Maximum beam, in. 21.60
Depth of main step, in. 1.04
Depth of main step, percent of beam 4.81
Center of gravity forward of step, in. 5.80
Center of gravity above keel, in. 26.50
Angle of dead rise at main step (angle between
  horizontal and line drawn from chine tangent
  to keel), deg. 18.5
Angle between keel aft of main step and keel
  forward of main step, deg. 7.0
Forebody, percent of length to second step 56.4
Maximum beam, percent of length to second step . . . 22.2

APPARATUS AND PROCEDURE

A description of the NACA tank and the towing carriage
is given in reference 3. The towing gear used in these
tests is described in reference 4.

The model was tested by the general method in the
same manner that the 1/12—full—size model was tested with
the center of moments at the position of the center of
gravity. The model was tested at the same trims and
through ranges of load and speed corresponding to the
ranges through which the 1/12—full—size model was tested,
the ranges being increased in accordance with Froude's
law of comparison for the increased size of the model.
In order to facilitate direct comparisons, the load param-
eters that were tested were made to correspond with those
used in the tests with the smaller model. (There was no
change in the density of the water between the tests of
the two models.)

In addition to the fixed—trim tests a general free—
to—trim test, which did not include high speeds, was made.
In the free—to—trim test the model was balanced to bring
the center of gravity of the model to the position corre-
sponding to the center of gravity of the full—size hull.
The load parameters were the same as those used in the
fixed—trim tests.

As is the usual practice in the NACA tank, the air
drag of the towing gear was obtained by making runs with-
out the model. The tare resistance was then deducted
from the gross resistance to obtain the net air—plus—
water resistance of the model.

In order to correlate the data from the present tests
with the results from the R.A.E. tank, an approximate cor-
rection for the air drag of the model was obtained by tow-
ing the model in air close to the surface of the water.
This procedure corresponds to the method used in deriving
the results from the R.A.E. tank (reference 1). The cor-
rection thus obtained is given by the equation:

$$\Delta R = 0.095 V_F{}^2$$

where ΔR is the correction in pounds to be subtracted
from the full—size resistance as derived from NACA tank
tests in order to correspond to full—size resistance as
derived from R.A.E. tank tests and V_F is the full—size
speed in knots. This correction was applied only in the
figures showing comparisons between the NACA and R.A.E.
data.

No corrections were applied to the trimming moments
obtained in the NACA tank tests, although in the R.A.E.
tank the aerodynamic moment was eliminated in a manner
similar to that for resistance described in the fore-
going paragraph. At high speeds, at which the aerodynamic
moment on the model is appreciable, the trimming moments
from the two tanks should, therefore, show some differ-
ences because of this difference in procedure alone. The
trims obtained in free—to—trim tests should differ for
the same reason.

Drafts were measured at the main step as a conven-
ient point of reference even though the afterbody some-
times was in the water deeper than the main step.

RESULTS

Test Data

The results from the fixed—trim tests are shown in
figures 2 to 19. Each figure represents one value for
trim and the load on the model is the parameter in all
cases. The variations of resistance, trimming moment,
and draft with speed are plotted in figures 2 to 7,
figures 8 to 13, and figures 14 to 19, respectively. The
free—to—trim results are shown in figures 20 and 21, in

which resistance and trim are plotted against speed with the load as a parameter.

In order to obtain exact comparisons, the results for the 1/12-full-size model have been converted to 1/6 full size and are shown by dotted lines in figures 2 to 21.

Nondimensional Data

The trim for minimum resistance is determined by cross-plotting resistance against trim for selected speed parameters. The data thus determined for best trim are converted to the following nondimensional coefficients:

Speed coefficient, $\quad C_V = \dfrac{V}{\sqrt{gb}}$

Load coefficient, $\quad C_\Delta = \dfrac{\Delta}{wb^3}$

Resistance coefficient, $\quad C_R = \dfrac{R}{wb^3}$

Trimming-moment coefficient, $\quad C_M = \dfrac{M}{wb^4}$

where

V speed, feet per second

g acceleration of gravity, feet per second per second

b maximum beam of hull, feet

Δ load on water, pounds

w specific weight of water, pounds per cubic foot
     ($w = 63.5$ lb/cu ft for the water in the NACA tank
     during these tests)

R resistance, pounds

M trimming moment, pounds-feet

Any other consistent set of units may, of course, be used.
The data, converted to these coefficients, are shown in
figures 22 to 25. In figure 22, C_R is plotted against
C_Δ with C_V as a parameter, and, in figure 23, C_R is
plotted against C_V with C_Δ as a parameter. Figure
24 shows τ_O, the best trim, plotted against C_V with
C_Δ as a parameter. Figure 25 shows C_M at τ_O plotted
against C_V with C_Δ as a parameter.

COMPARISON WITH EARLIER TESTS

Compared With NACA 1/12—Full—Size Model

Scale effect.— The present tests were not undertaken
for the purpose of establishing the order of the scale
effect encountered in tank tests. The testing of only two
models would be inadequate for such an investigation.
Tests dealing with scale effect are reported in references
1, 5, and 6. The minimum—size model for satisfactorily ac-
curate conversion of model data to full size, on the basis
of Froude's law of comparison, is discussed in each of
these references; and the size of the model normally tested
in the NACA tank appears to be larger than the average of
the minimum sizes recommended. The present 1/6—full—size
model is slightly larger than the size normally tested in
the NACA tank.

Resistance.— Examination of the curves of figures 2
to 7 shows, as might be expected, a general tendency for
the converted resistance of the 1/12—full—size model to
be greater than the resistance for the 1/6—full—size model.
The smaller model consistently indicates a greater hump
resistance, and the percentage differences generally in-
crease with load and decrease with increasing trim. The
maximum differences at the hump, which are of the order of
15 to 20 percent, occur at small trims and, as a result,
would not be noted in a normal take—off. In the range of
trims that would normally occur in take—offs the differ-
ences in the hump resistance are less than 8 percent. The
differences in resistance just above the hump speed, when
converted to the same size, are inconsistent for the two
models but are, in general, less than the differences at
the hump.

At the higher speeds, the converted resistances are, in general, larger for the smaller model than for the larger model. On a percentage basis the differences at high speeds are extremely large but, because a large part of the total air-plus-water resistance of a seaplane at high speeds is caused by air drag, the effect of the differences on take-off calculations is considerably less than it would first appear to be.

Trimming moment.— In figures 8 to 13 the curves for the small model are consistently above those for the large model, indicating that the center of pressure is relatively farther forward on the small model than on the large model. This fact is further demonstrated in figure 21, where it is seen (that the trim is consistently greater for 1/12-full-size model than for the 1/6-full-size model.) These results are in agreement with the results described in references 1 and 6.

Compared With R.A.E. 1/6-Full-Size Model

The results obtained in the NACA and R.A.E. tanks have been converted to correspond to a full-size gross load of 27,300 pounds. The wing lift was applied according to the lift-coefficient curve given in figure 16 of reference 2 for a wing area of 1760 square feet. The data for the R.A.E. tank were taken from figures 24, 26, and 27 of reference 1.

In the curves of trimming moment from the R.A.E. tests the aerodynamic moment of the model was deducted; in the NACA curves it is not deducted. The resistance values for the tests from both tanks were corrected for the air drag of the model. The curves representing the data from the NACA tank tests were obtained from figures 2 to 13, 20, and 21 by cross-plotting resistance, trimming moment, and trim against load at selected speeds and by determining the values of these variables for the computed loads.

A comparison of the results of the free-to-trim tests made in the two tanks should show differences in trims because, in the R.A.E. tests, aerodynamic moment on the model was eliminated. The resistance obtained in the NACA tank at the trims given in the results of the R.A.E. free-to-trim tests was determined from the NACA fixed-trim data. The resistance thus determined is compared with the free-to-trim resistance from the R.A.E. tank in figure 26. The agreement here is considered to be especially good.

A comparison of the resistances obtained in the two tanks for trims at three different speeds is shown in figure 27. The agreement here is, in general, considered to be satisfactory. An exception occurs at high trims for a speed of 53.2 knots. In this region the NACA model was riding on the afterbody with the main step clear of the water.

A comparison of the trimming moments, at the same three speeds mentioned previously, is shown in figure 28. The values of the trimming moments found in the NACA tests are consistently smaller than those obtained in the R.A.E. tests.

These comparisons indicate that the results of the NACA and R.A.E. tests of the 1/6-full-size model show about the same agreement as the results of previous tests made in the two tanks of a 1/12-full-size model. The differences in resistance and trimming moment observed in the tests of the 1/6-full-size and the 1/12-full-size models in the NACA tank might at first appear to be greater than those obtained in the R.A.E. tests of two models of the same scales, but a close inspection shows that the large discrepancies in the NACA data for the two models were obtained under conditions that were not tested in the R.A.E. tank, that is, at large loads, small trims, and very high speeds.

CONCLUSIONS

1. There is some scale effect indicated by the results from the tests with the 1/6- and 1/12-full-size models. The results are such that if the full-size resistance is computed in the usual manner, it will be larger when computed from the results of the tests of the smaller model than it would be if the results from the larger model were used. Because it has been established that the larger model will give more reliable results, it may be concluded that the full-size resistance would be overestimated by using the results from the tests with the smaller model.

2. A comparison of the data from the NACA tests of the 1/6-full-size model with the data from the R.A.E.

tests of a model of the same size shows that the results
are in substantial agreement.

Langley Memorial Aeronautical Laboratory,
      National Advisory Committee for Aeronautics,
            Langley Field, Va., June 9, 1942.

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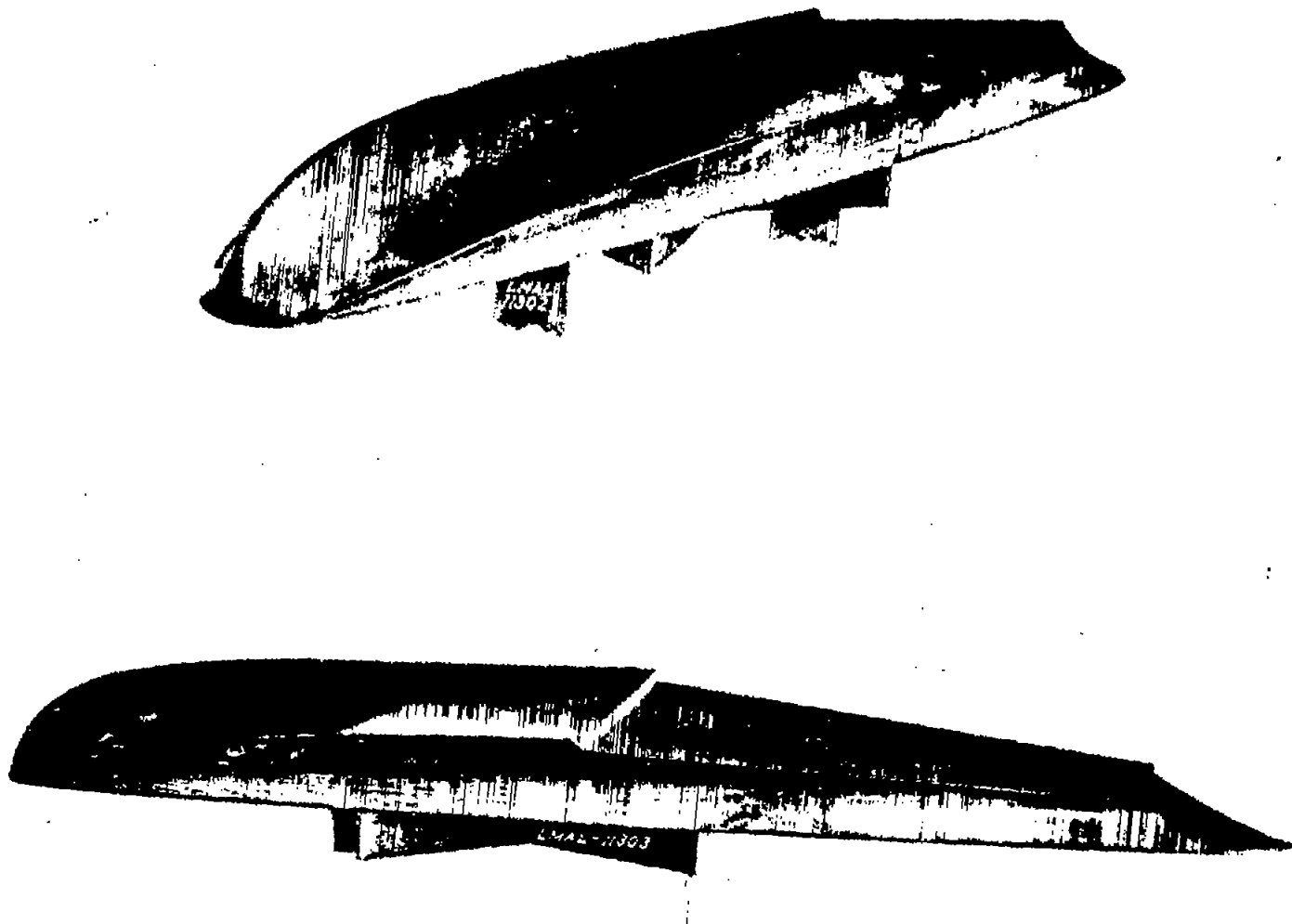
Figure 1.— Photographs of model 58.

Fig. 1
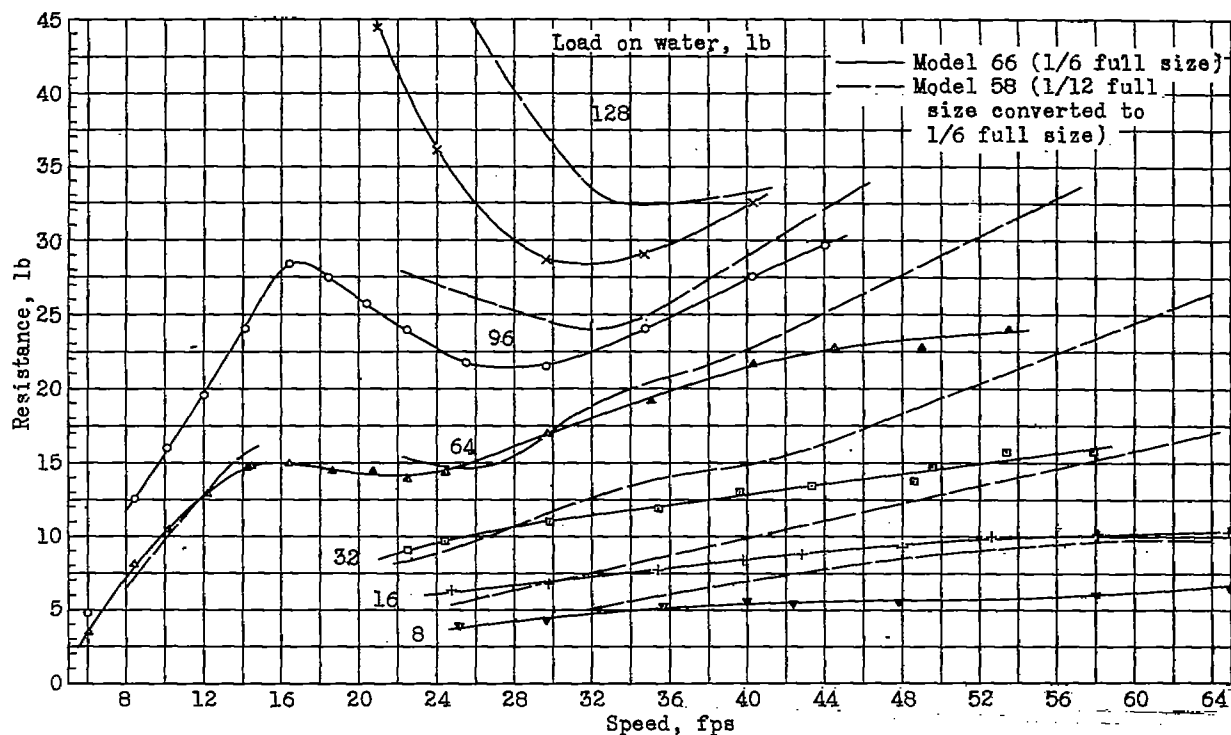
Figure 2.- Models 66 and 58. Variation of resistance with speed, $\tau = 3°$.
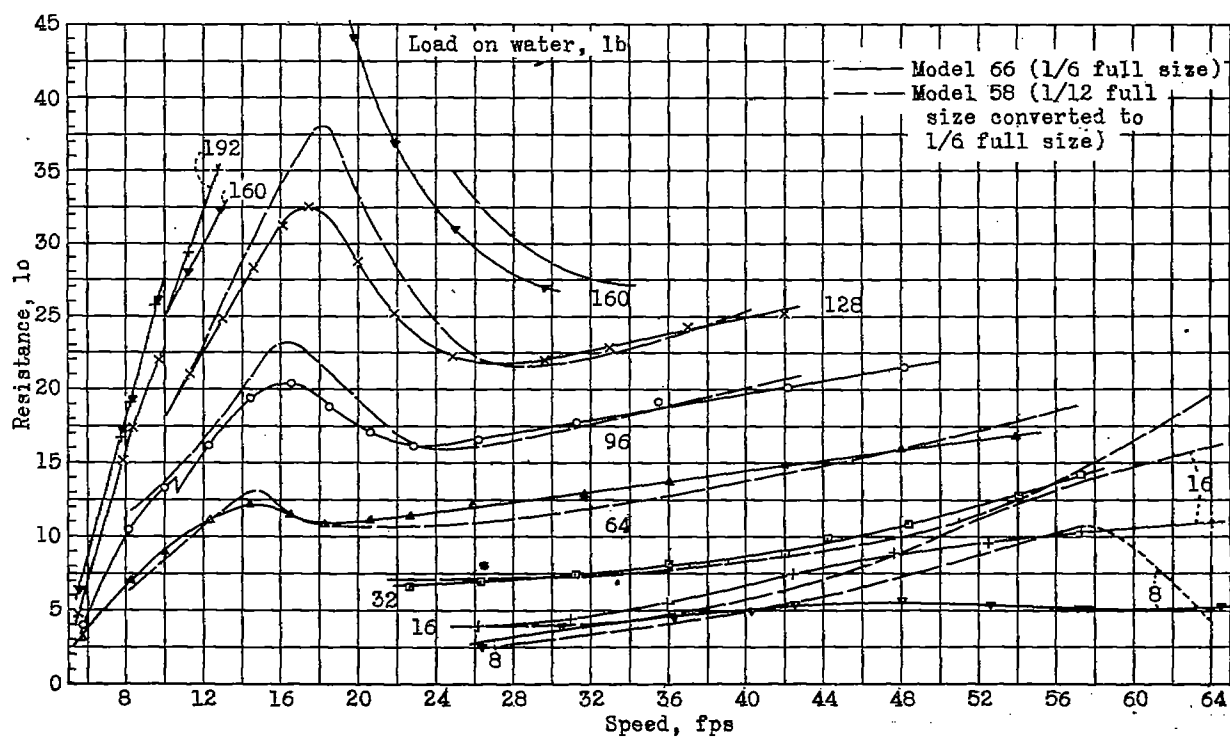
Figure 3.- Models 66 and 58. Variation of resistance with speed, $\tau = 5°$.
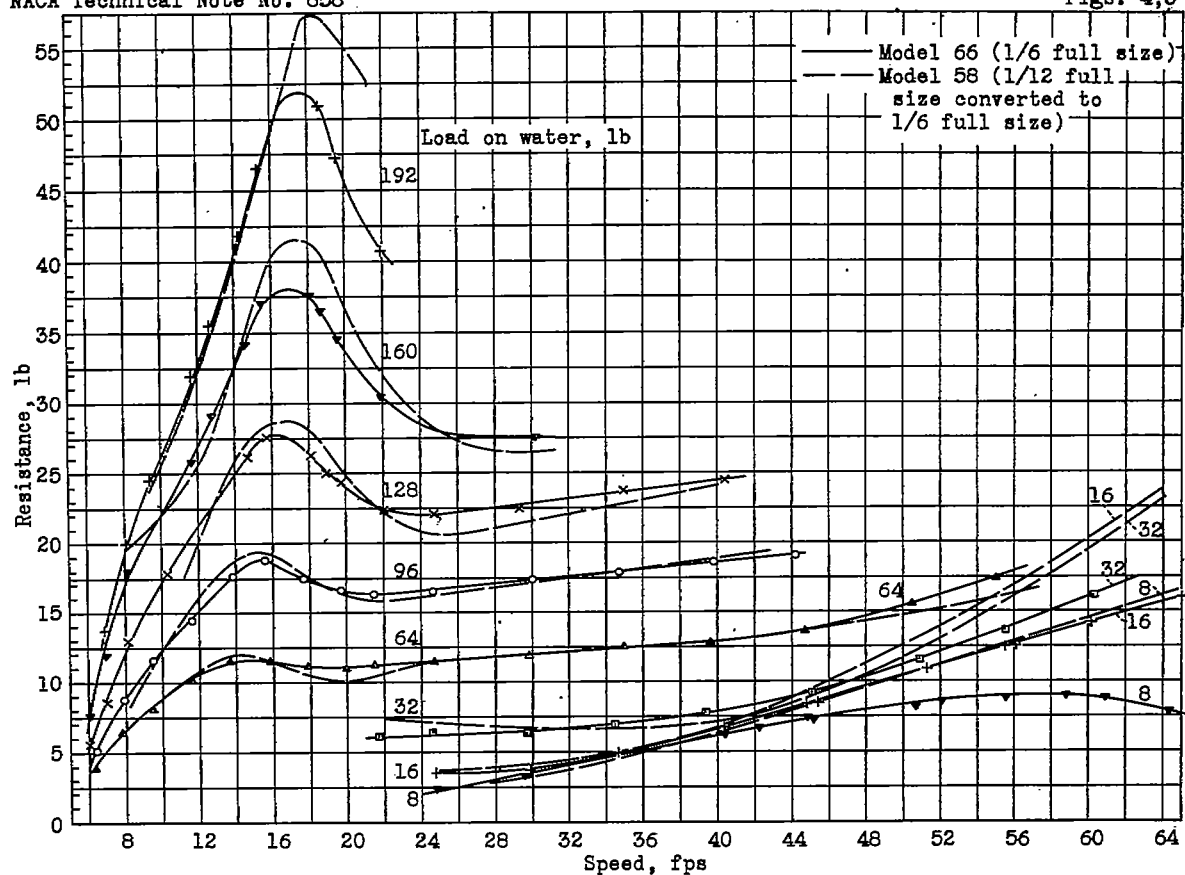
Figure 4.- Models 66 and 58. Variation of resistance with speed, $\tau = 7^o$.
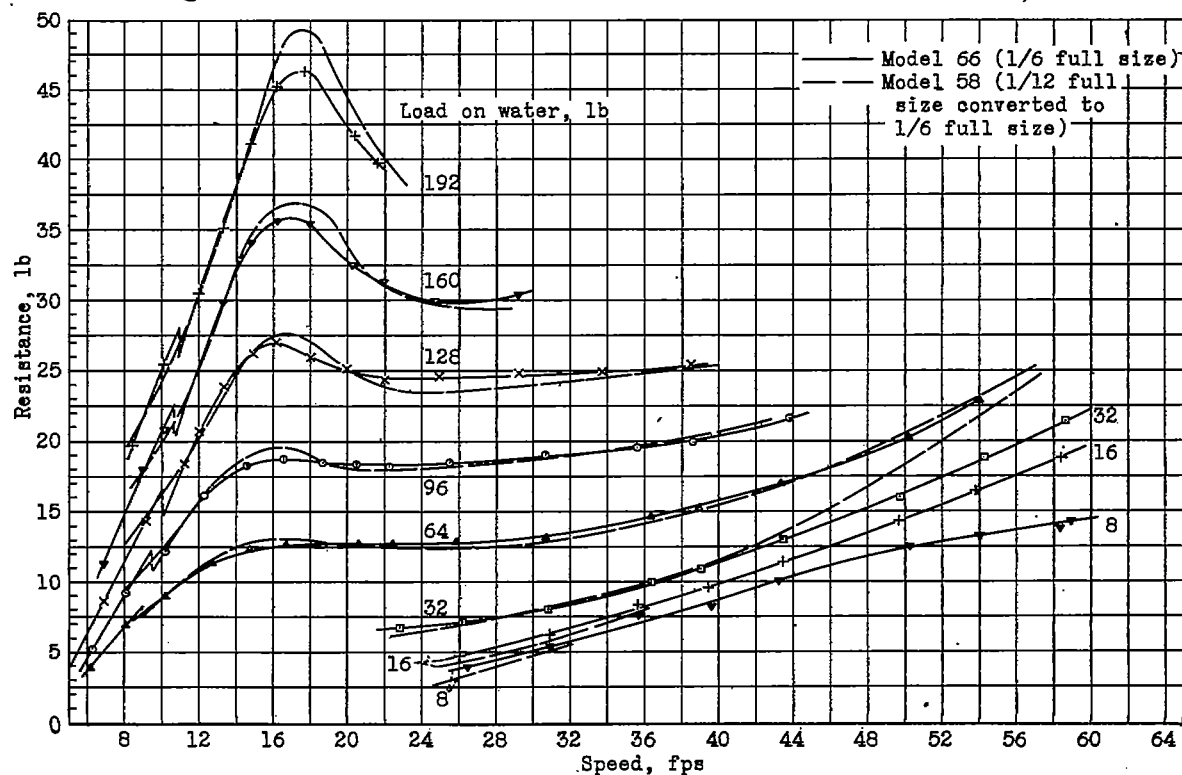
Figure 5.- Models 66 and 58. Variation of resistance with speed, $\tau = 9^o$.
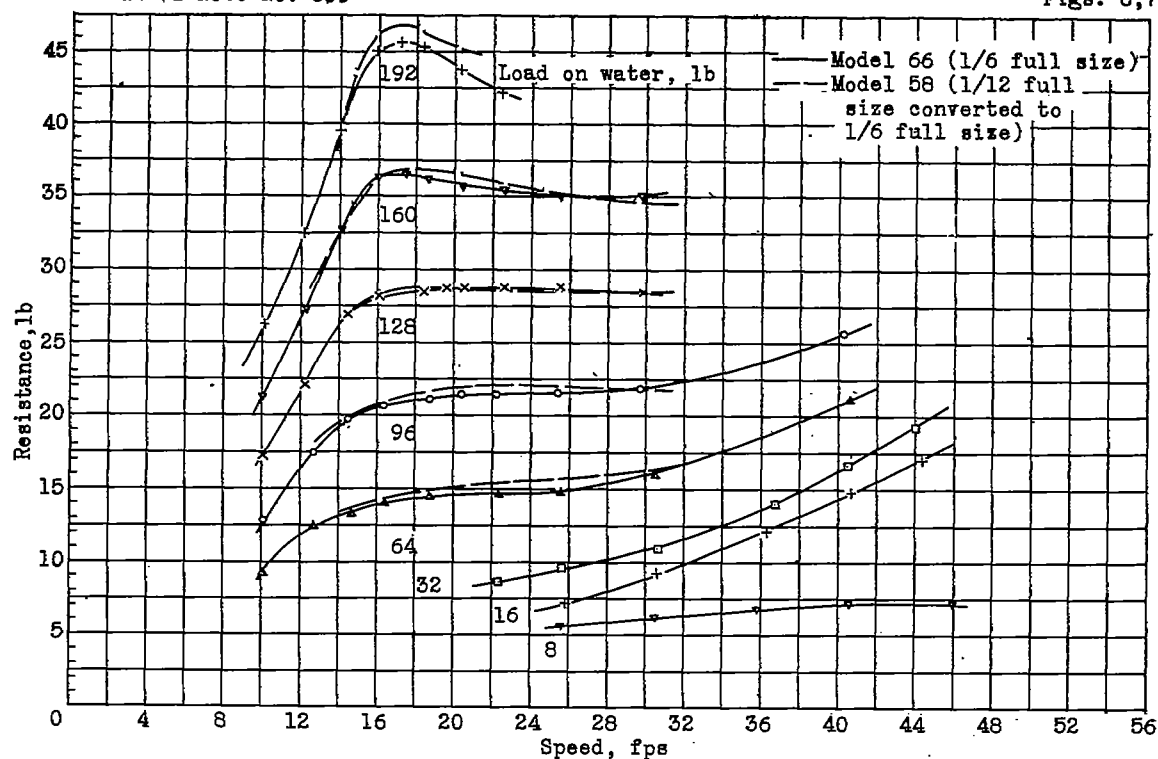
Figure 6.- Models 66 and 58. Variation of resistance with speed, $\tau = 11°$.
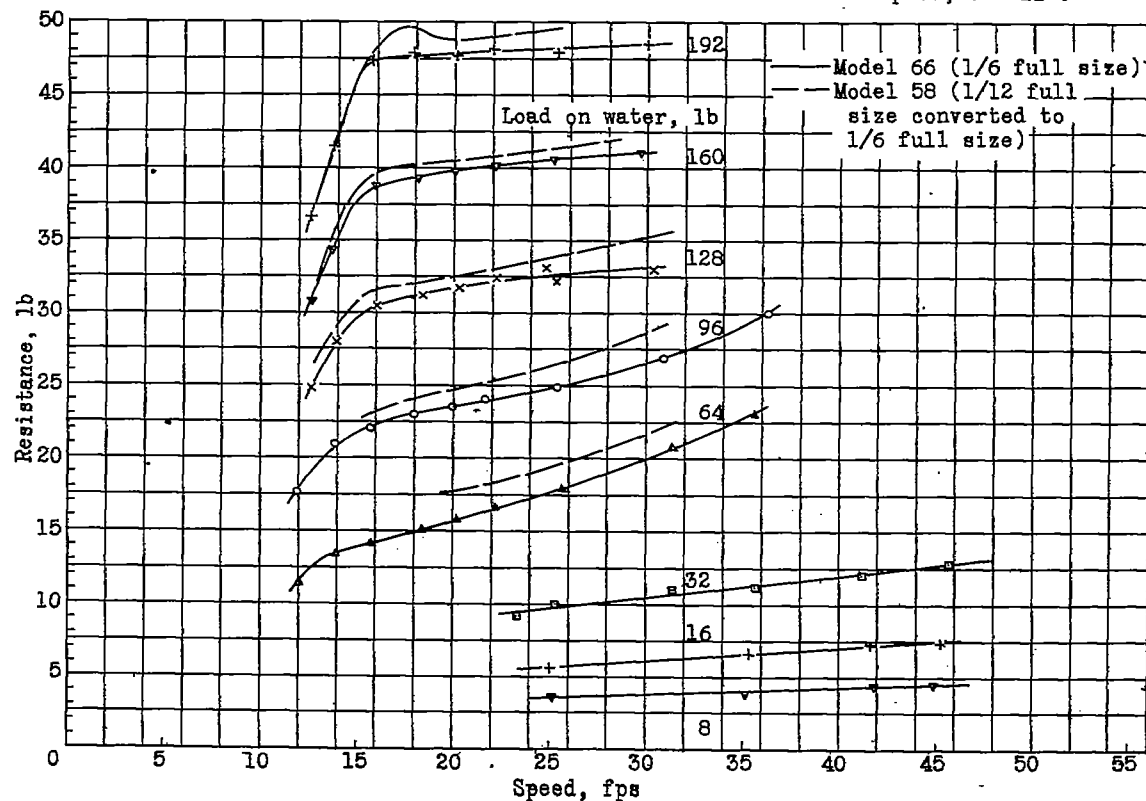
Figure 7.- Models 66 and 58. Variation of resistance with speed, $\tau = 13°$.
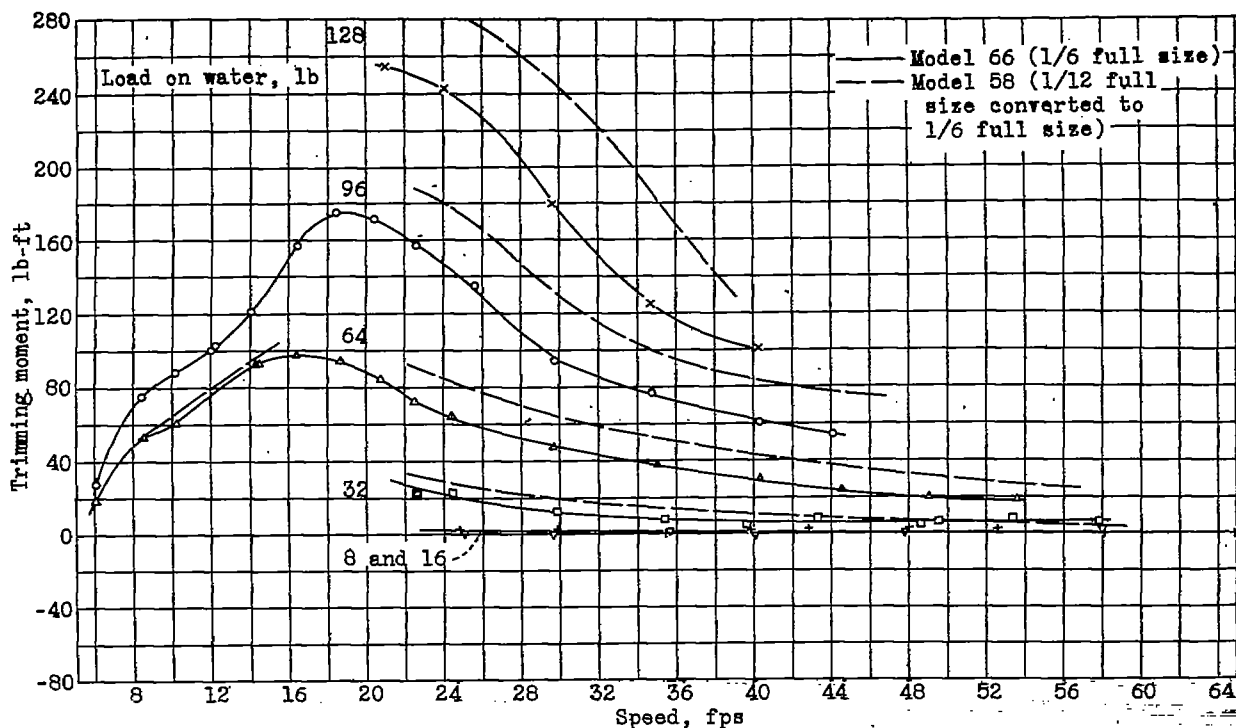
Figure 8.- Models 66 and 58. Variation of trimming moment with speed, $\tau = 3^\circ$.
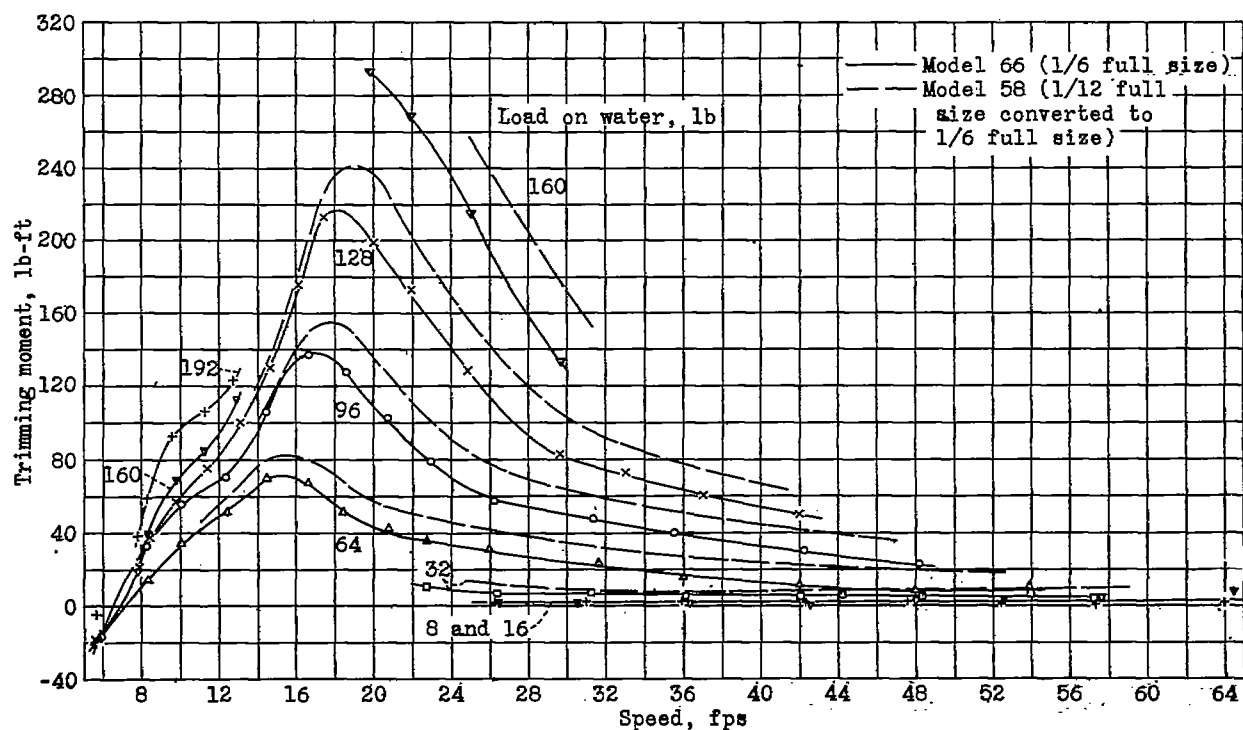
Figure 9.- Models 66 and 58. Variation of trimming moment with speed, $\tau = 5^\circ$.
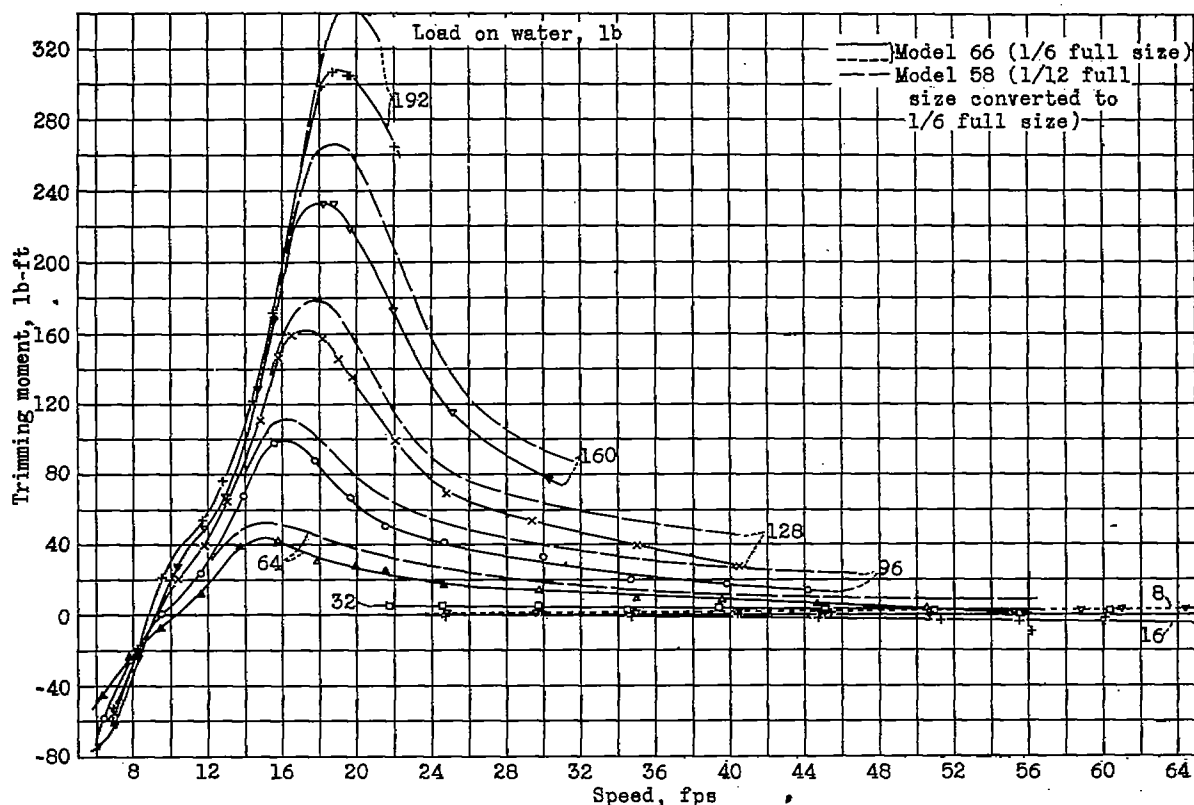
Figure 10.- Models 66 and 58. Variation of trimming moment with speed, $\tau = 7^{\circ}$.
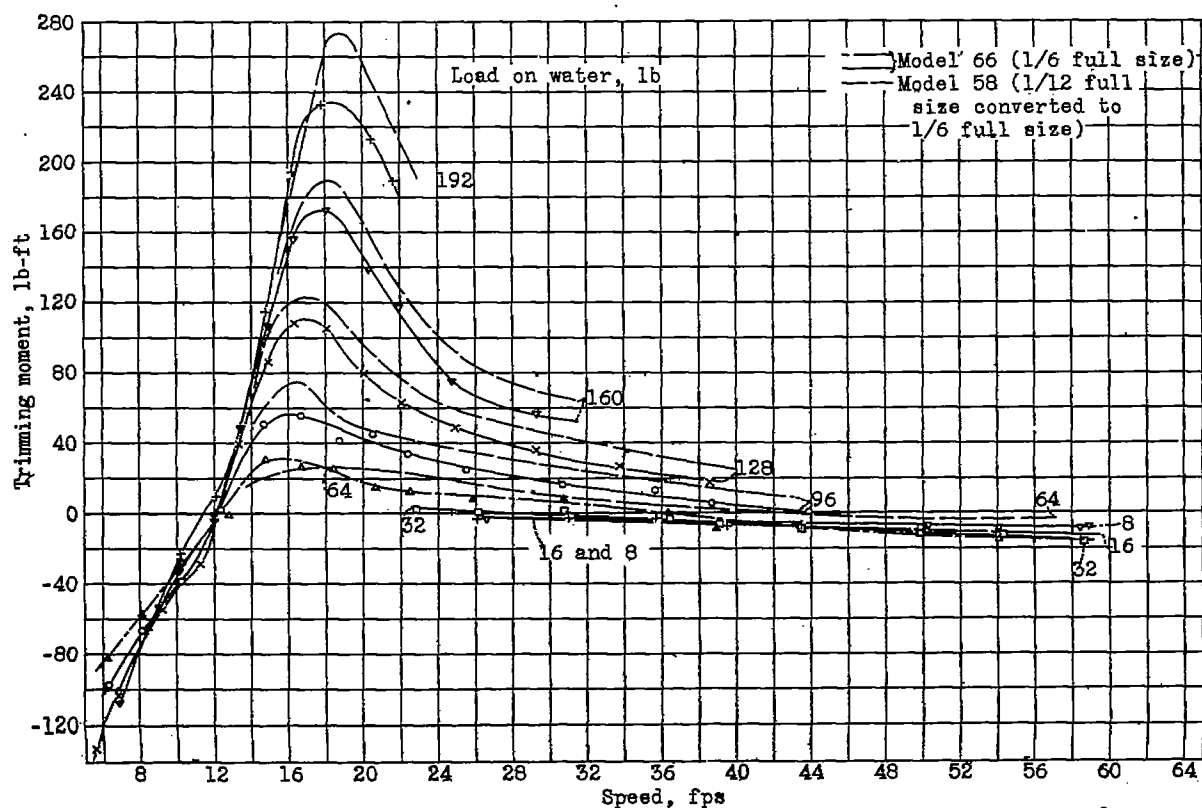
Figure 11.- Models 66 and 58. Variation of trimming moment with speed, $\tau = 9^{\circ}$.
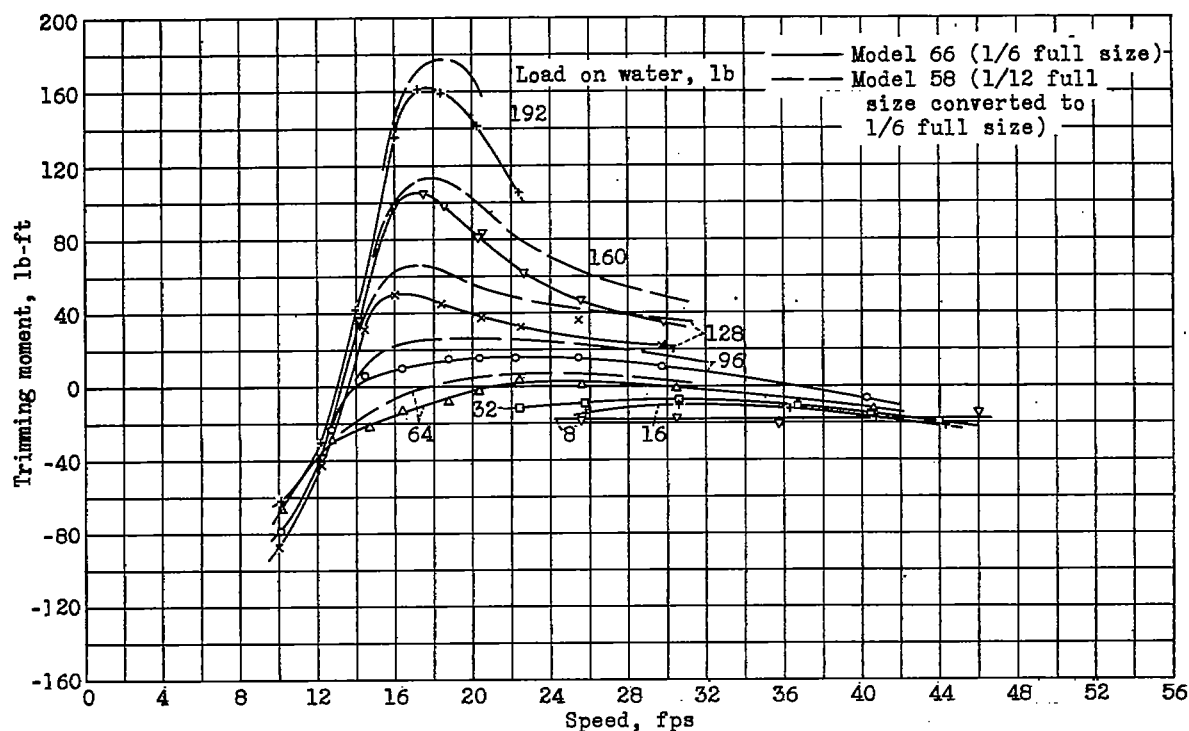
Figure 12.- Models 66 and 58. Variation of trimming moment with speed, $\tau = 11°$.
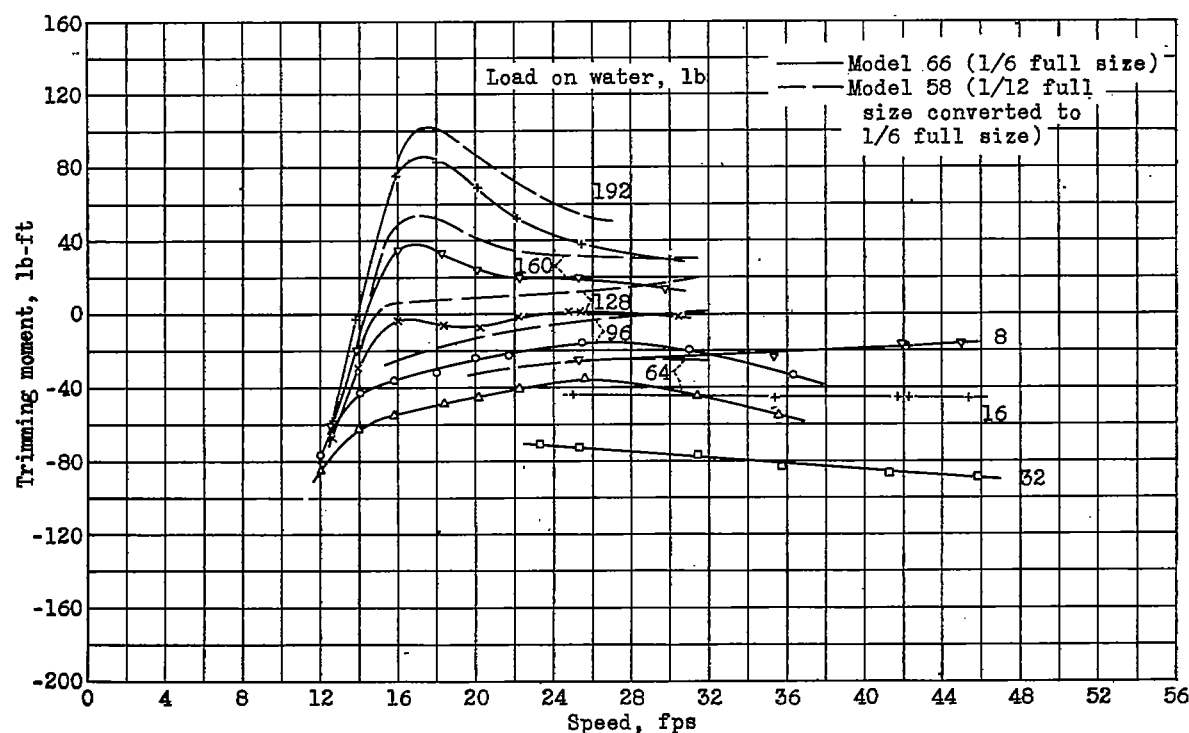
Figure 13.- Models 66 and 58. Variation of trimming moment with speed, $\tau = 13°$.
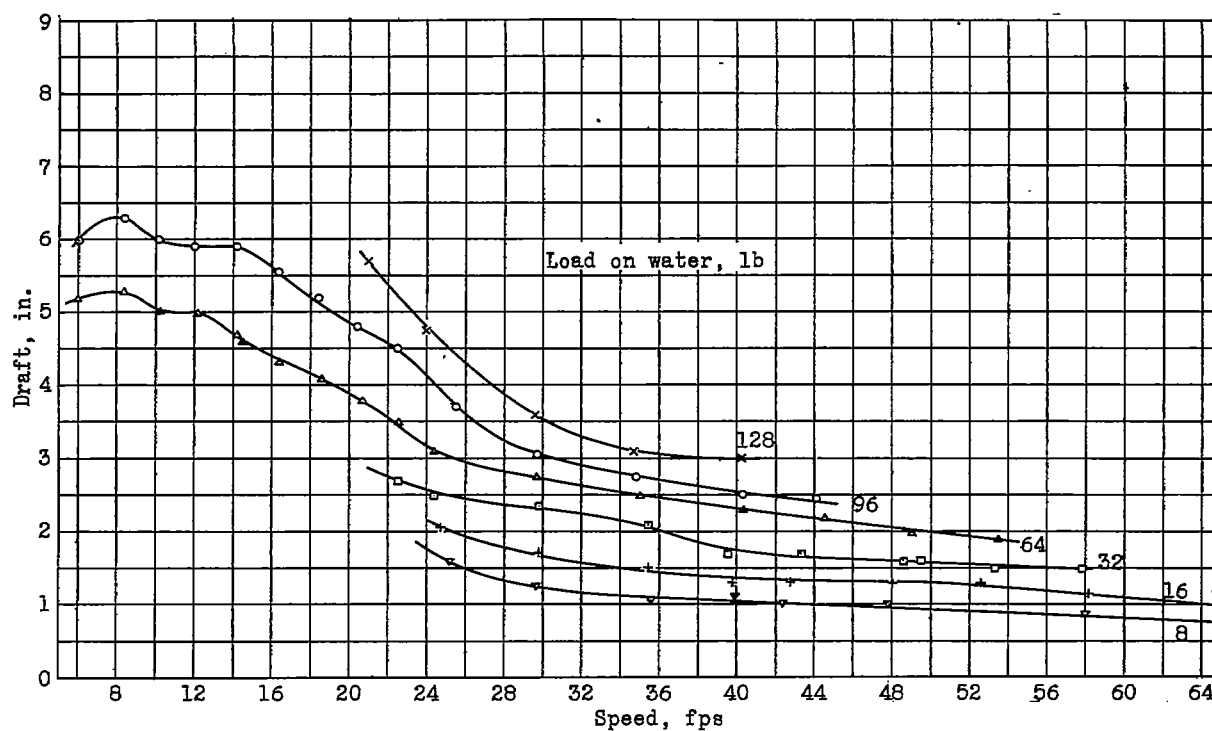
Figure 14.- Model 66. Variation of draft with speed, $\tau = 3^o$.
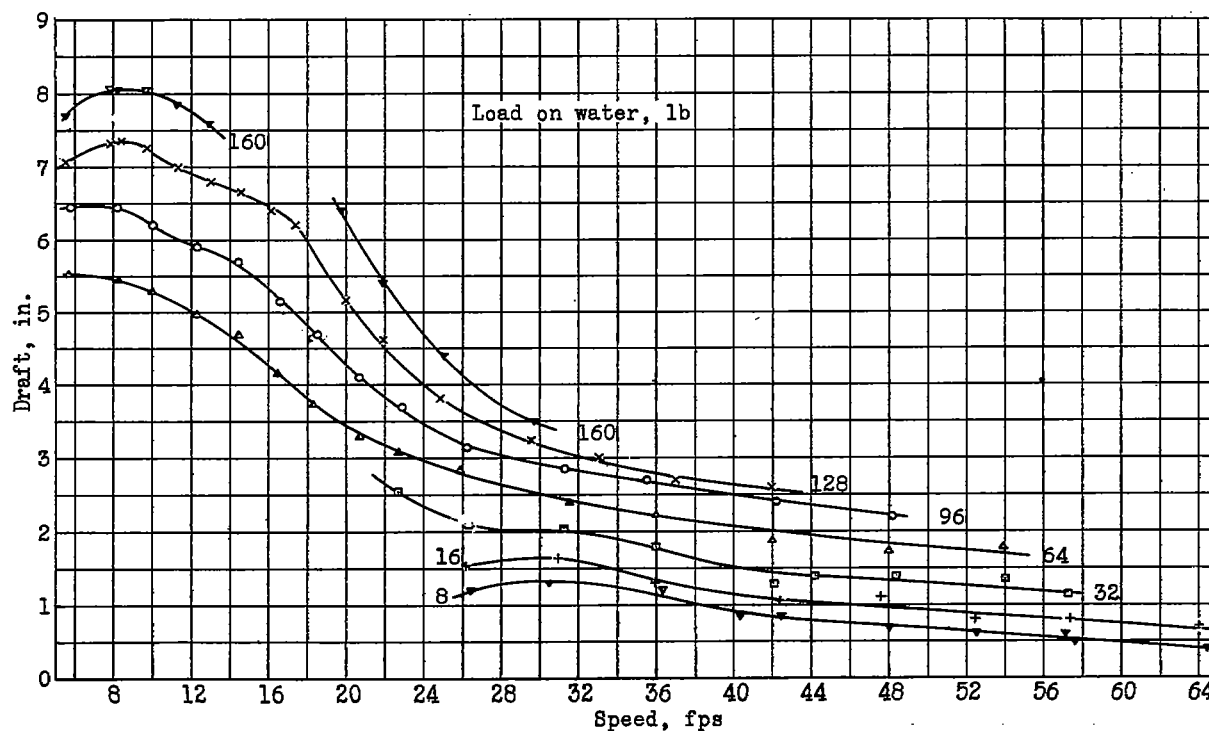
Figure 15.- Model 66. Variation of draft with speed, $\tau = 5^o$.
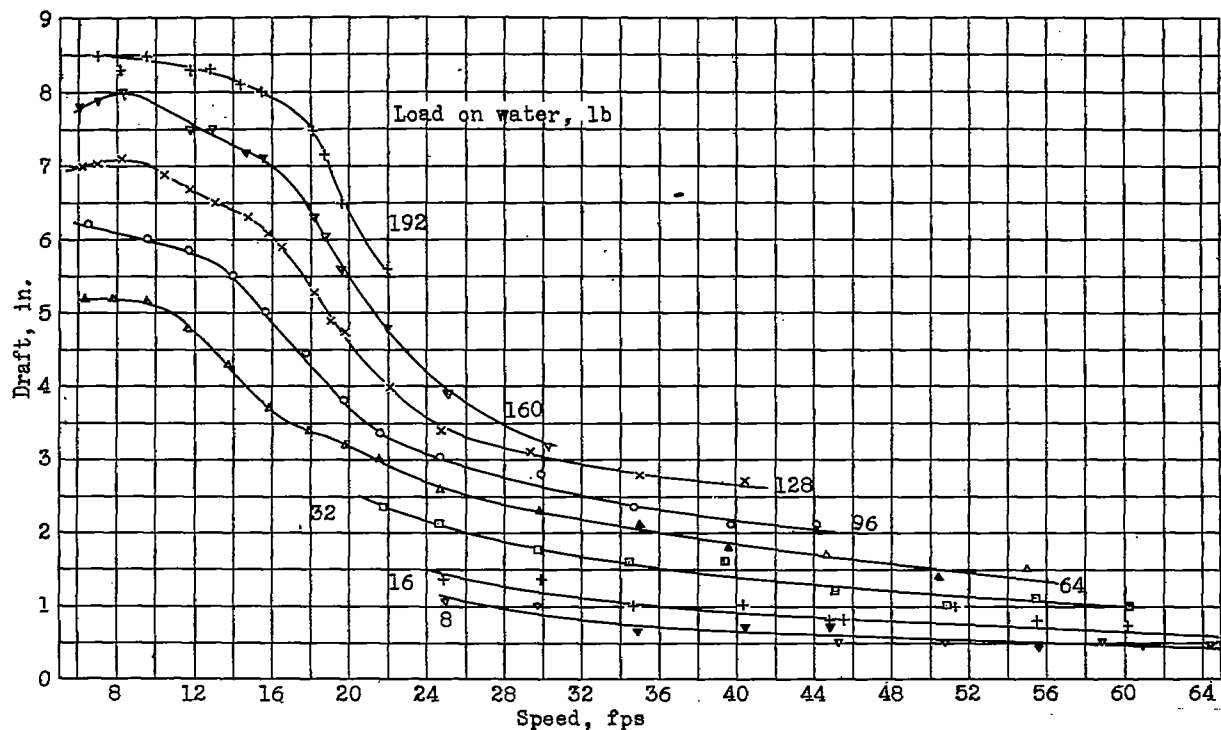
Figure 16.- Model 66. Variation of draft with speed, $\tau = 7^{\circ}$.
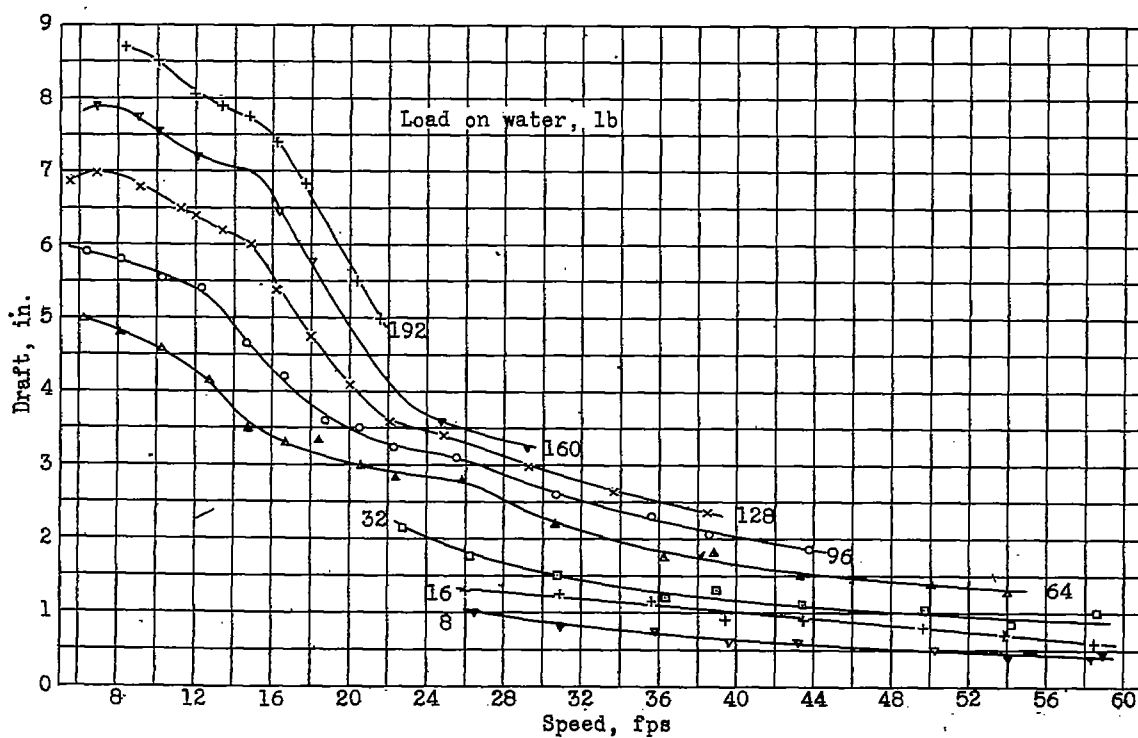
Figure 17.- Model 66. Variation of draft with speed, $\tau = 9^{\circ}$.
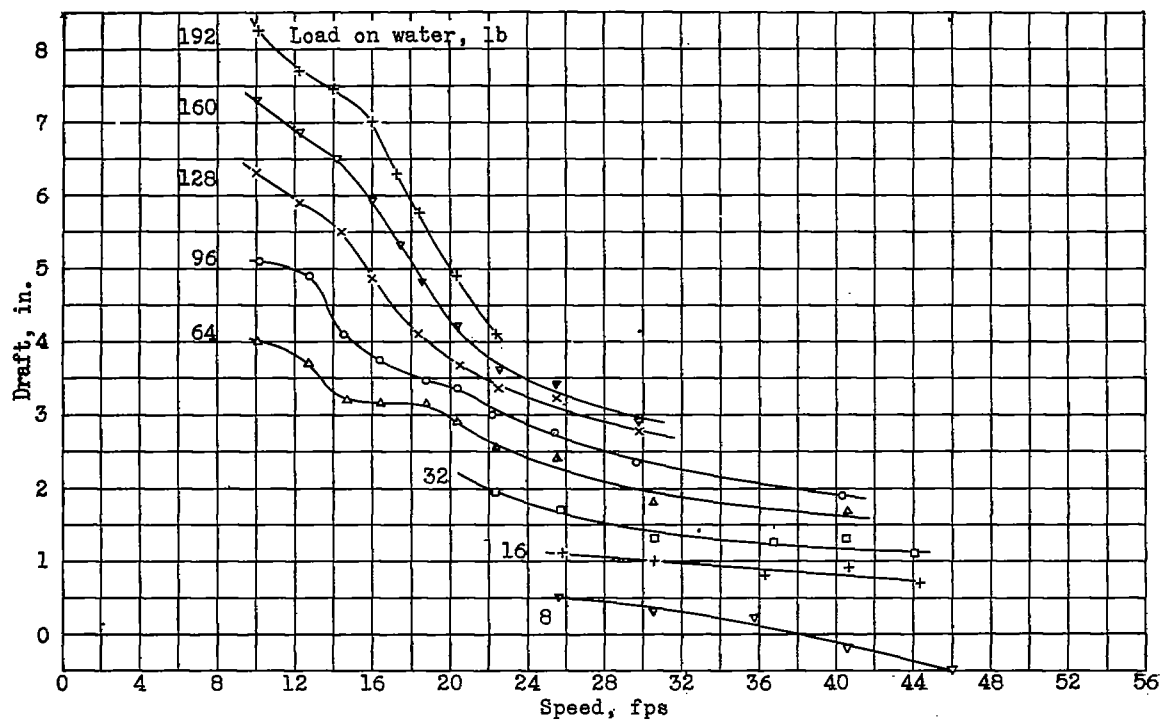
Figure 18.- Model 66. Variation of draft with speed. $\tau = 11^{\circ}$.
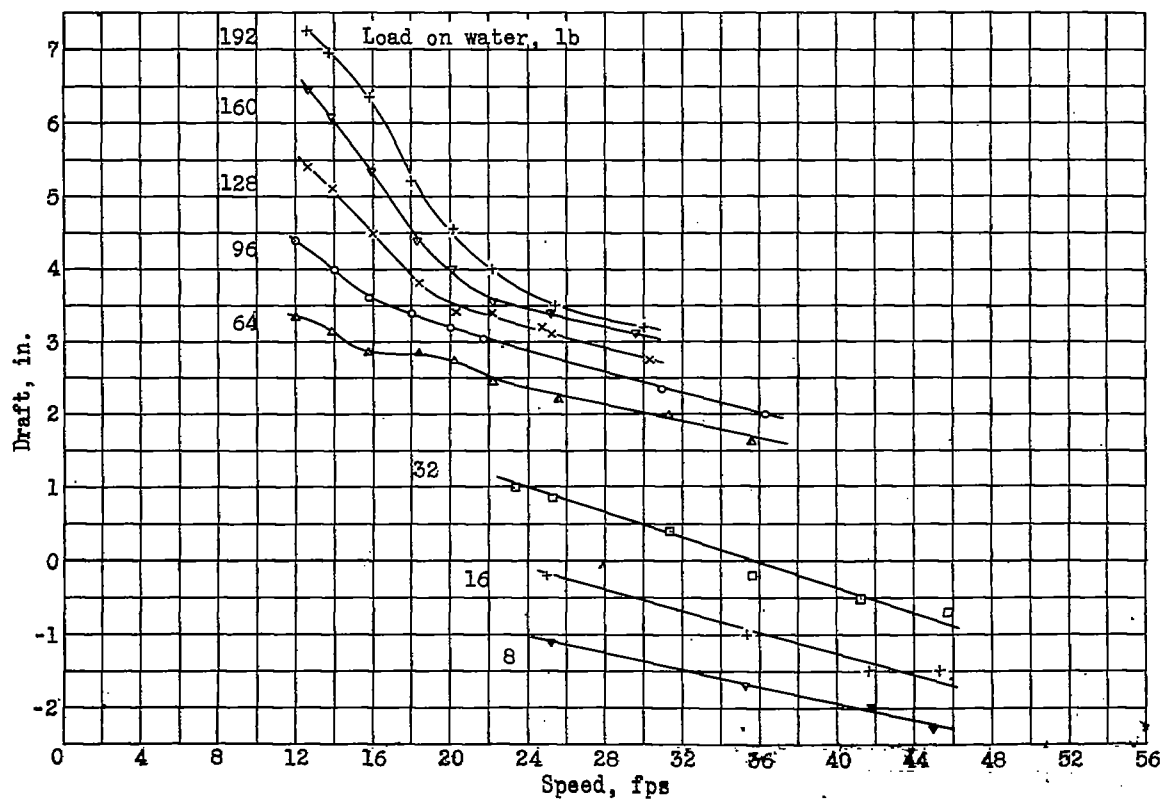
Figure 19.- Model 66. Variation of draft with speed. $\tau = 13^{\circ}$.
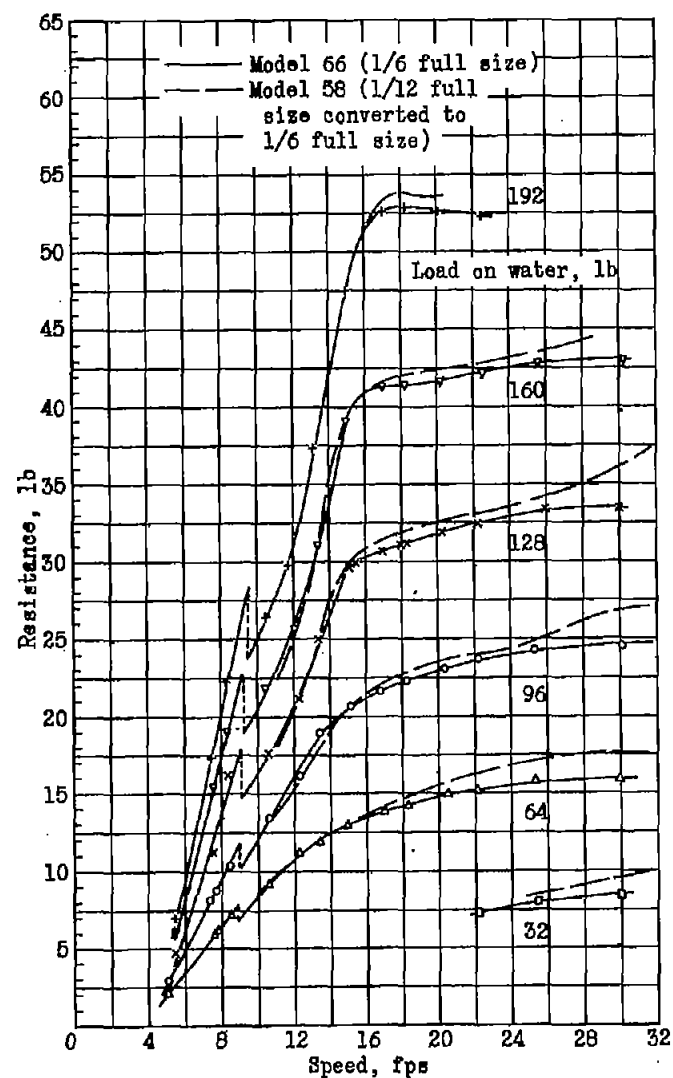
Figure 20.- Models 66 and 58. Variation of resistance with speed, free-to-trim.
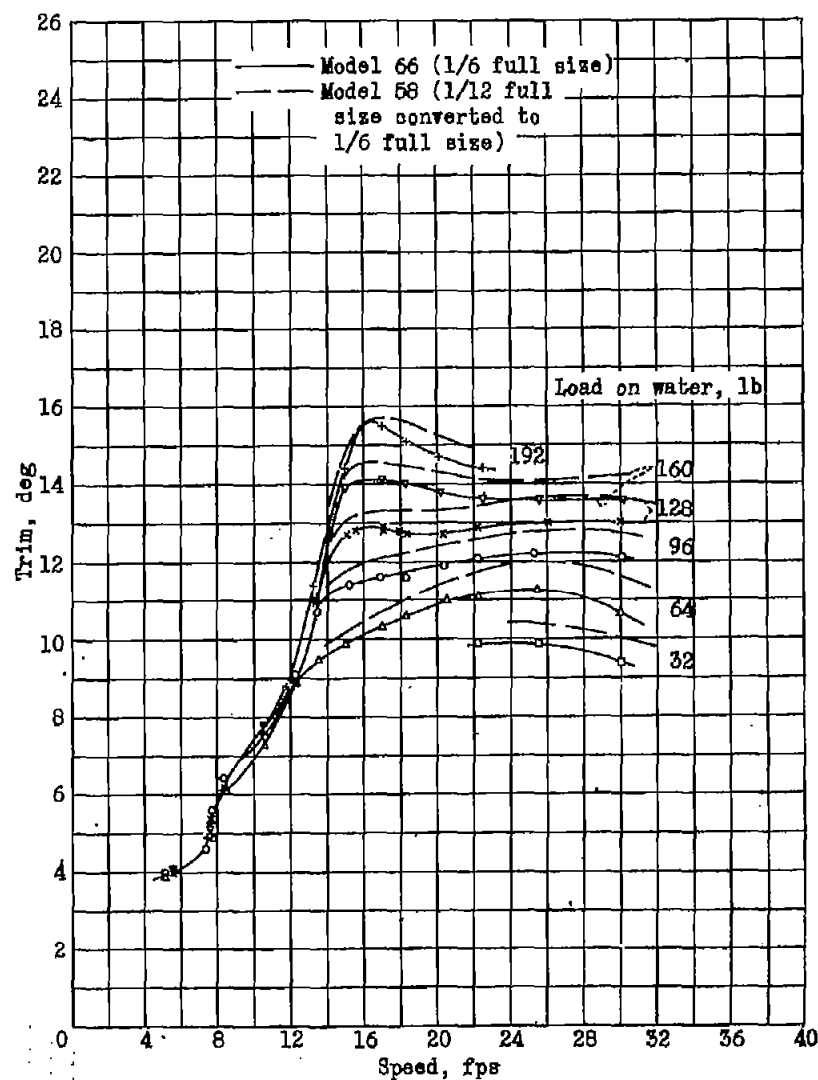
Figure 21.- Models 66 and 58. Variation of trim with speed, free-to-trim.
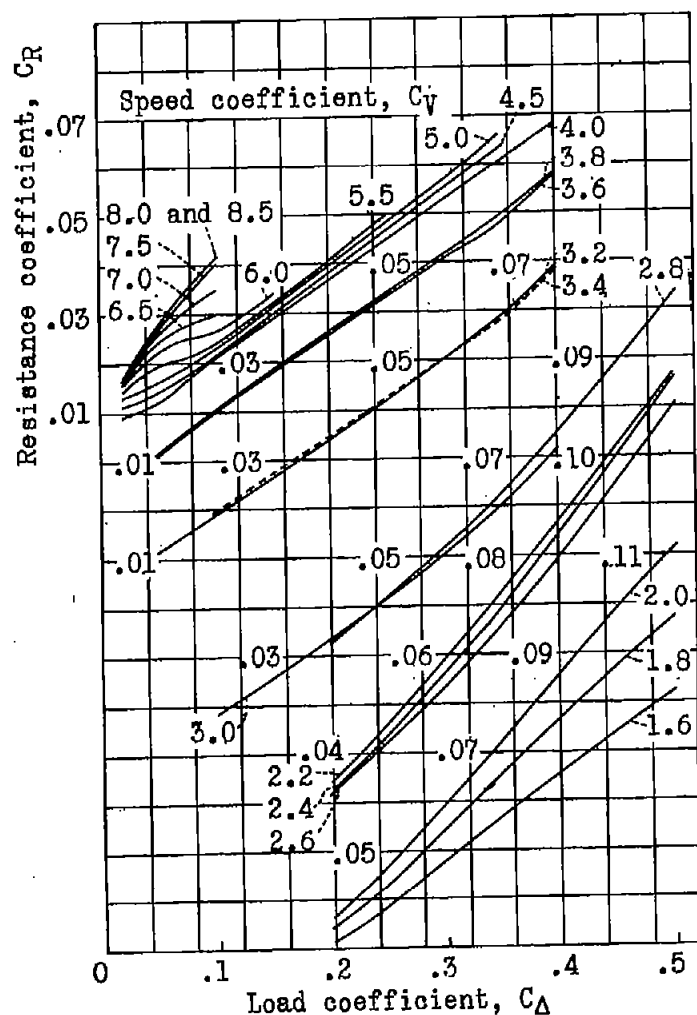
Figure 22.- Model 66. Variation of resistance coefficient at best trim with load coefficient.
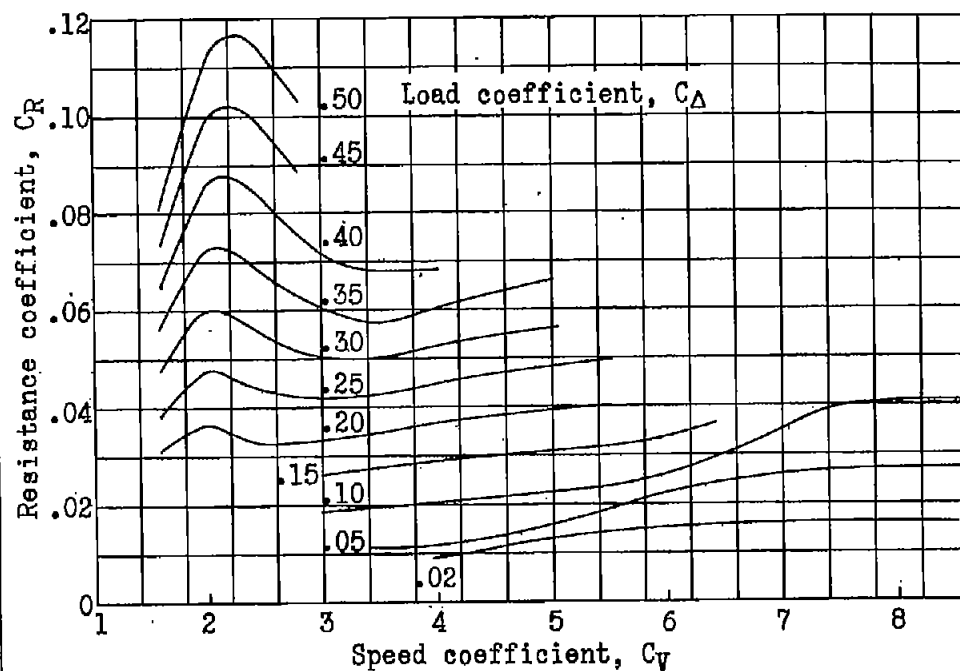
Figure 23.- Model 66. Variation of resistance coefficient at best trim with speed coefficient.
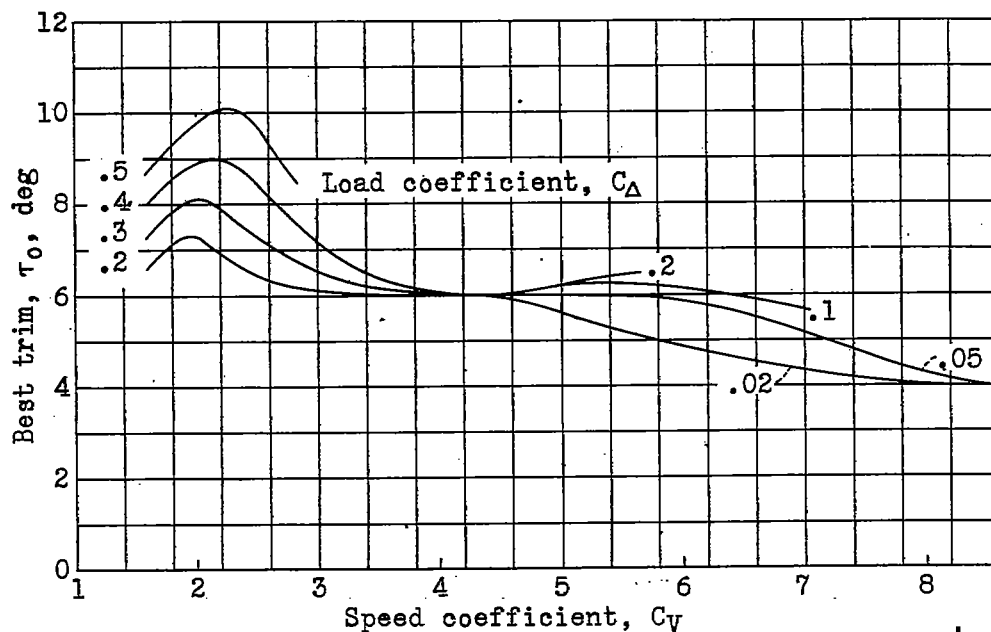
Figure 24.- Model 66. Variation of best trim with speed
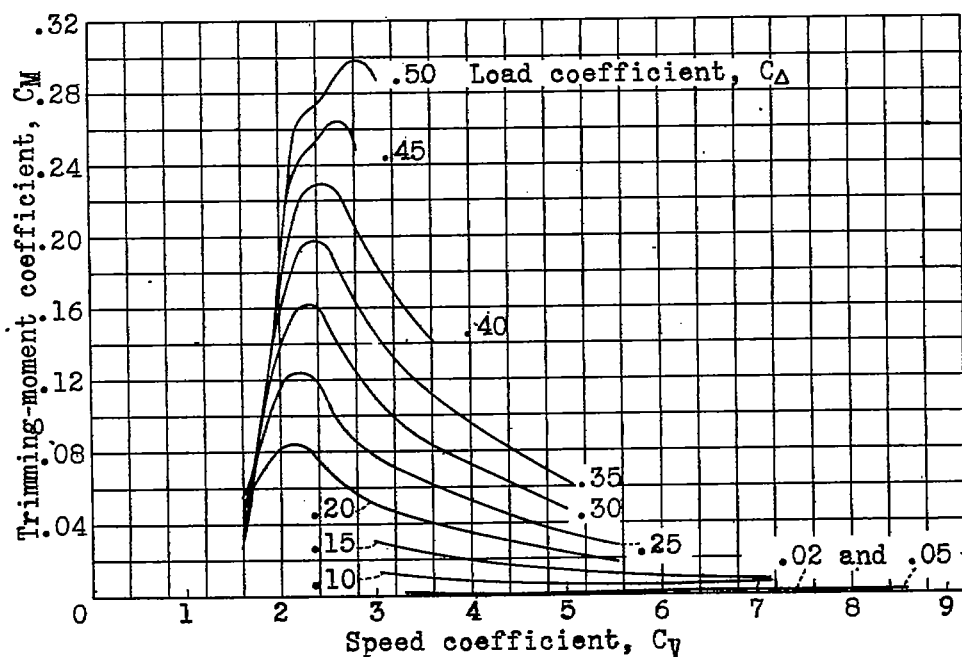coefficient.

Figure 25.- Model 66. Variation of trimming-moment coef-
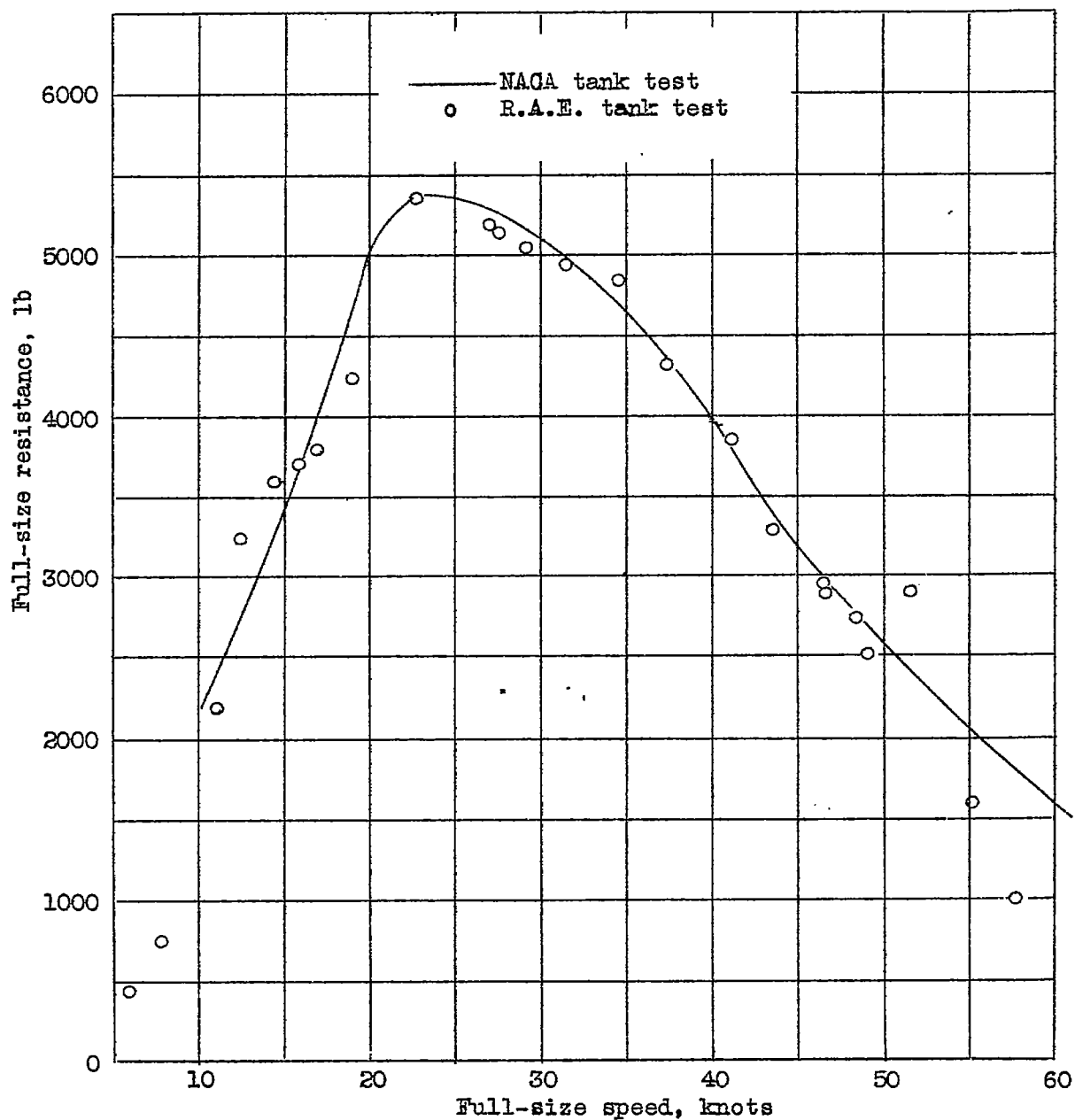ficient at best trim with speed coefficient.

Figure 26.- Model 66. Comparison of free-to-trim resistance from
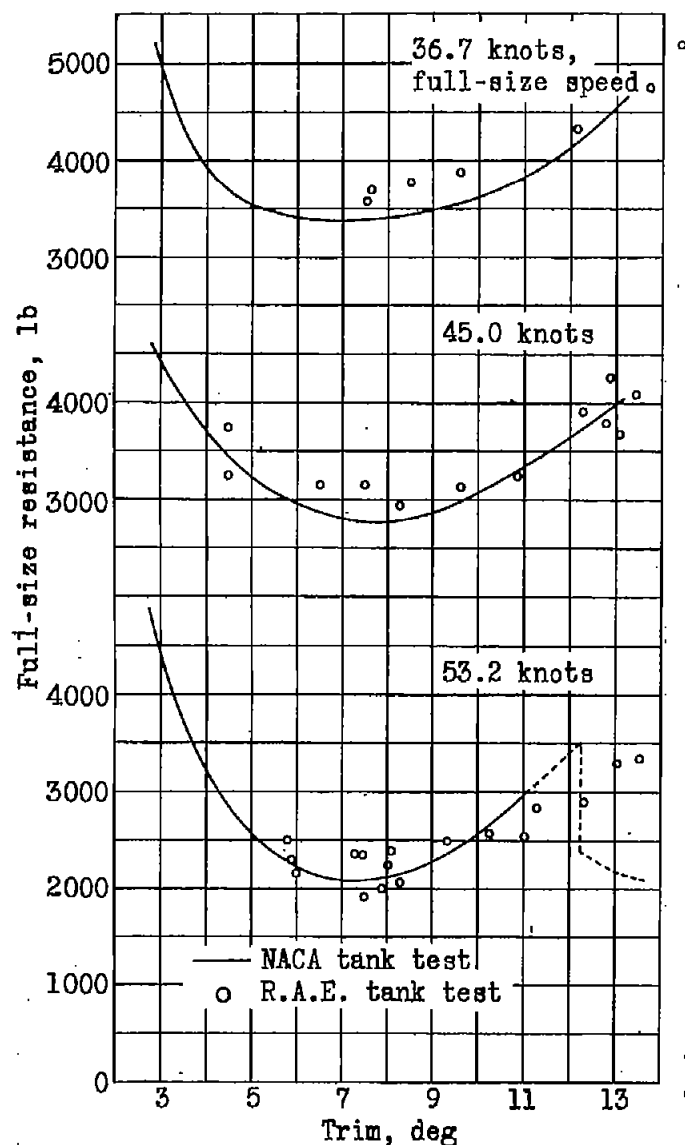R.A.E. tank with resistance obtained in NACA tank
at same trims.

Figure 27.- Model 66. Comparison of resistance
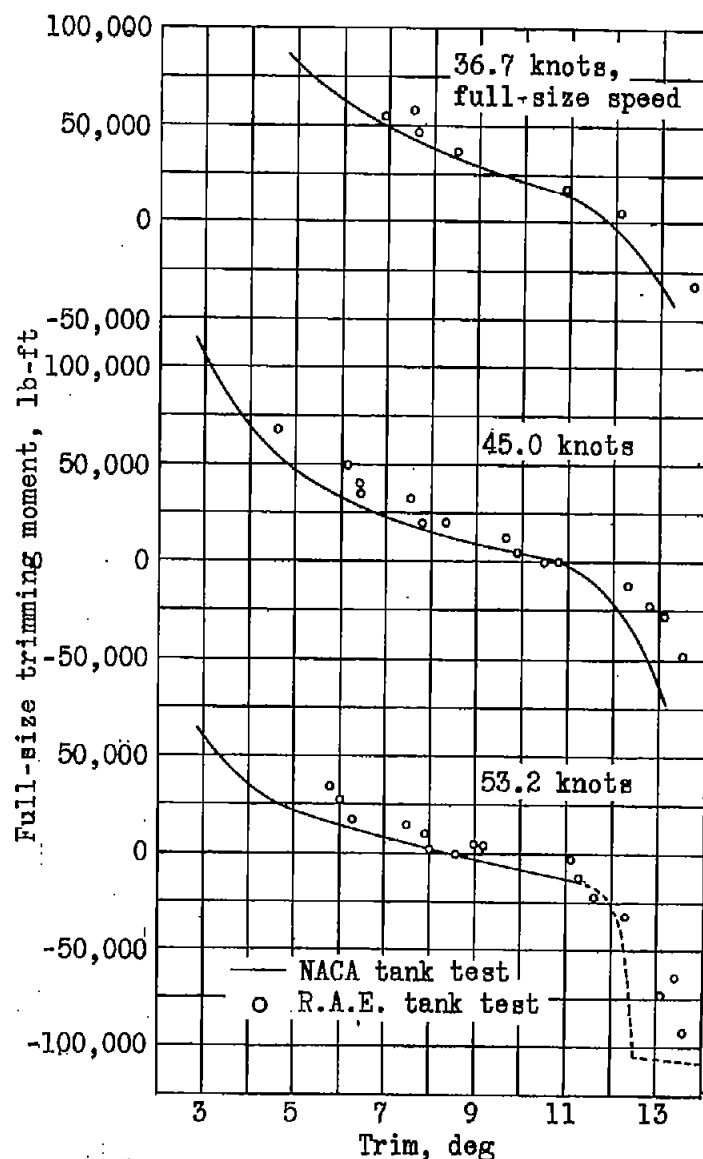obtained in NACA and R.A.E. tanks.

Figure 28.- Model 66. Comparison of trimming
moments obtained in NACA and R.A.E. tanks.